Understanding the carbon footprint of electricity from wind and solar in European Union and their dependency on foreign supply chains: an input-output approach

Topic: Energy Policies
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In the context of climate change concern and global economic instability, the European Union (EU) aims to reduce the consumption of fossil fuels in favor of renewables in its power mix, increasing the penetration of photovoltaic (PV) and wind technologies in particular. However, similarly to fossil fuels, a significant share of the supply-chains of such technologies lies outside the European borders. To ensure a sustainable and secure transition, policymakers need to be aware of the environmental impacts of each technological alternative as well as their level of economic dependency on foreign supply-chains.

A first key question, therefore, is: (i) is it possible to determine the degree of dependency from foreign economies of new power generation technologies? Furthermore, how do they compare with fossil technologies?
Another crucial aspect, in line with the goals of the energy transition, is the ability of PV and wind power to generate electricity with significantly lower GHG emissions compared to fossil-fuelled alternatives. Nowadays, more and more emissions are being released to enable the production of transition energy technologies.
A second key question emerges: (ii) is what is produced today (i.e., photovoltaic panels and wind turbines) going to pay back the emissions required to produce it quickly enough?

Although many studies effectively address the second question raised, none attempts to answer the first, related to backward supply-chain dependency. Life Cycle Assessment (LCA) methodologies are largely based on physical information, which has only recently been integrated with economic information. Typically, such analyses are the domain of input-output-based LCA, where both economic and physical information are considered within the same analytical boundaries. The resulting methodology is usually referred to as Environmentally-Extended Input-Output (EEIO) analysis. However, when used for LCA analyses, these models usually exclude the impacts associated with capital expenditures. Nevertheless, it is possible to extend the matrix of intermediate transactions to explicitly include those supply-chains that produce capital goods for companies. Thus, a hybrid LCA analysis is used to get such results.

This paper contributes to quantitatively assess this information, adopting a multi-regional input-output model based on the Exiobase dataset, properly extended to explicitly model the manufacturing processes of PV and wind power plants in the EU. This is done by using a multi-regional input-output model that explicitly accounts for the capital expenditures of these technologies. The model is based on the Exiobase 3.8 database, which covers 200 commodities, 163 industries and 49 regions for the years 2011-2019. The paper also uses an open-source software (MARIO) to handle the model and ensure the replicability of the analysis. The paper provides indicators such as carbon and energy footprints, payback times, energy return on investment, and backward linkages. The model provides a set of insightful indicators such as environmental footprints, carbon and energy payback times and input-output backward linkages.

It is found that PV and wind technologies have relatively low carbon footprints (85.7 and 30.2 gCO2eq/kWh for PV and wind respectively) and exhibit comparable external dependency to fossil-fueled alternatives. Furthermore, they demonstrate a quick payback in terms of emissions and

energy required for their production respect to their expected lifetime. Results are enriched with a sensitivity analysis considering different reference years of the Exiobase dataset and realistic ranges of technologies performances.